DRAFT 4/97

4.2 Test of Heat Conduction

4.2.1 2-D heat conduction in a square

These tests verify that FEHM correctly models 2-dimensional heat conduction. They also verify that the finite-element representation of 2-D 3-node triangles (triangular-element meshes), 4-node quadrilaterals (rectangular-element meshes), mixed-element meshes (containing both triangular and rectangular elements), and refined-element meshes (containing rectangular and trapezoidal elements) have been correctly implemented. Figures 25 and 25 show that FEHM results are in good agreement with the analytical solution for the 2-D heat-conduction simulations. The results, compared numerically to the analytical solution (found in files *heat2dout.analyt_pos* and *heat2dout.analyt_time*), are given in Table 43. The maximum absolute error for these four runs was less than 0.9°C, and the percent errors were less than 0.5%. These results meet the acceptance criteria for this test suite developed in Chapter III.

Table 43. Results of the test of 2-D heat conduction

V&V test	Maximum error	Maximum % error	RMS error
Temperature versus time at x = y = 0.0 m			
3-node triangles	0.5808	0.4166	0.7660e-04
4-node quadrilaterals	0.7141	0.3665	0.4060e-04
mixed elements	0.5526	0.2812	0.5129e-04
refined elements	0.8344	0.4315	0.4253e-04
Temperature versus position at t = 2.16e4 seconds			
3-node triangles	0.5980	0.3421	0.7418e-03
4-node quadrilaterals	0.7070	0.3651	0.8163e-03
mixed elements	0.6670	0.3466	0.7643e-03
refined elements	0.8615	0.4452	0.8726e-03

4.2.2 heat conduction in a cube

These tests verify that FEHM correctly models 3-dimensional heat conduction. They also verify that the finite-element representation of 3-D 6-node triangular prisms (prism elements), 8-node quadrilateral polyhedrons (brick elements), 4-node tetrahedrals, mixed-element meshes (containing both triangular prisms and quadrilateral polyhedrons), refined-element meshes (containing quadrilateral polyhedrons and trapezoidal polyhedrons), and the finite-volume option have been correctly implemented. Figures 25 and 25 show that FEHM results are in good agreement with the analytical solution for the 3-D heat-conduction simulations. The results, compared numerically to the analytical solution (found in files *heat3dout.analyt_pos* and *heat3dout.analyt_time*), are given in Table 44. The maximum absolute error for these seven runs was less than 1.3 °C, and the percent errors were less than 0.7%. These results meet the acceptance criteria for this test suite developed in Chapter III.

DRAFT 4/97

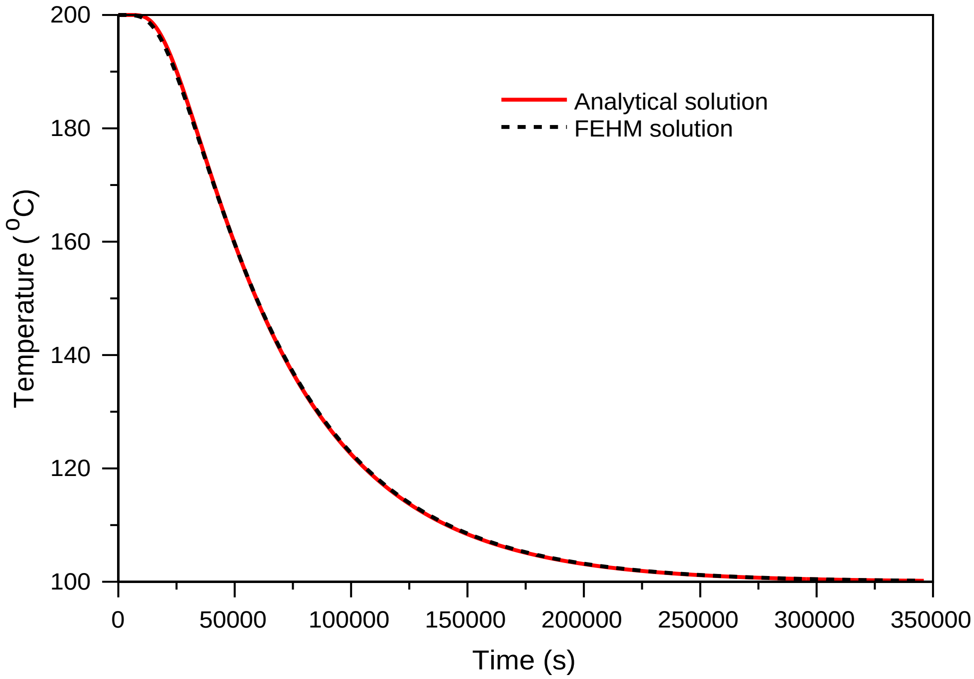

Figure 25. Comparison of FEHM and analytical solutions for 2-D heat conduction at coordinate position x = y = 0 m.

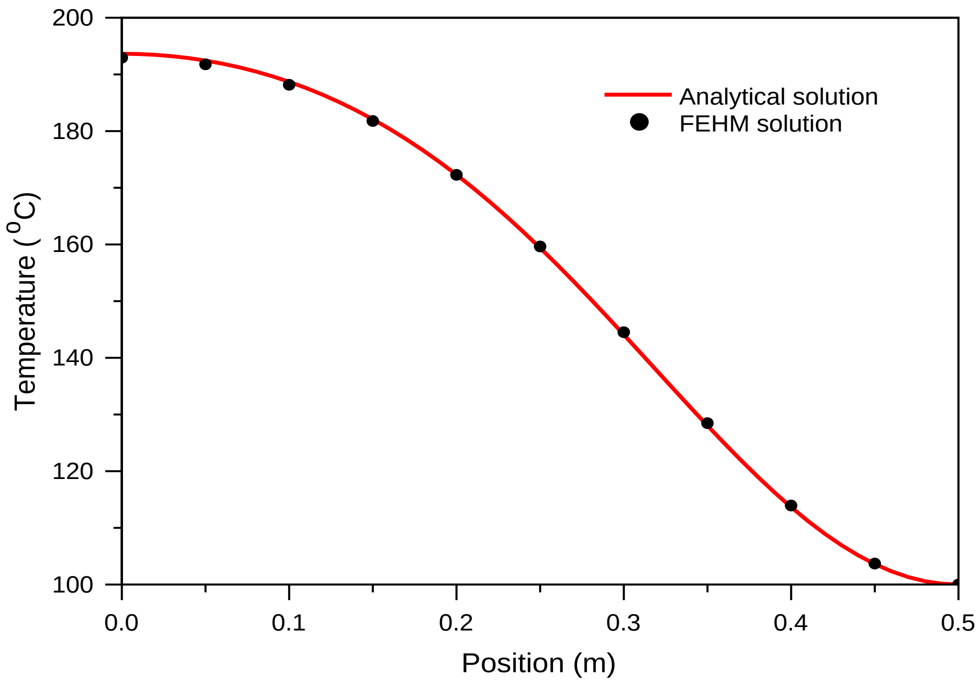

Figure 25. Comparison of FEHM and analytical solutions for 2-D heat conduction at time t = 2.16e4 seconds.

DRAFT 4/97

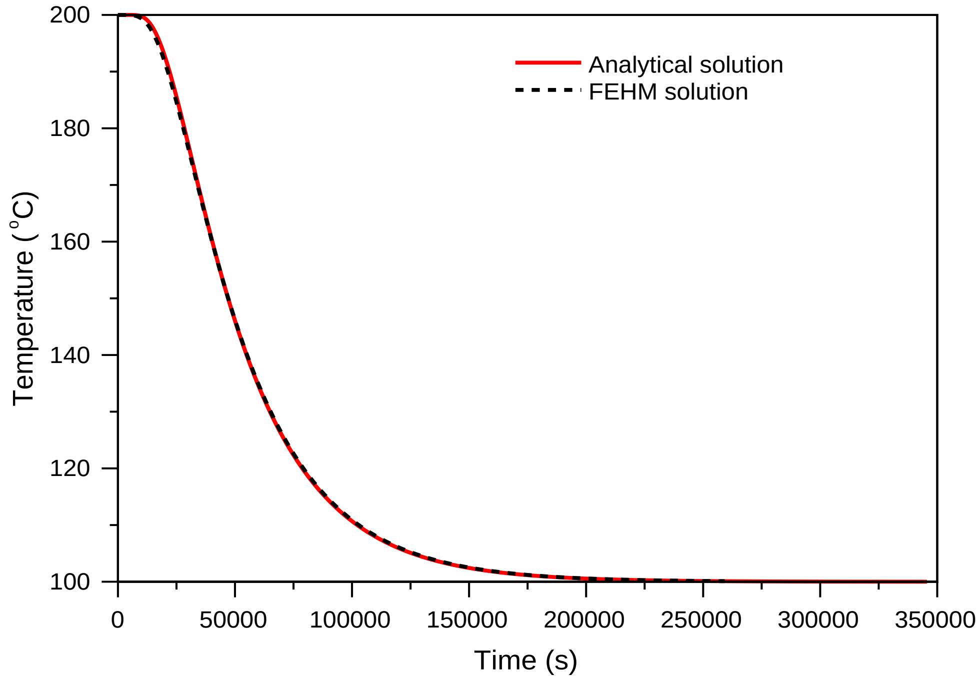

Figure 25. Comparison of FEHM and analytical solutions for 3-D heat conduction at coordinate position x = y = z = 0 m.

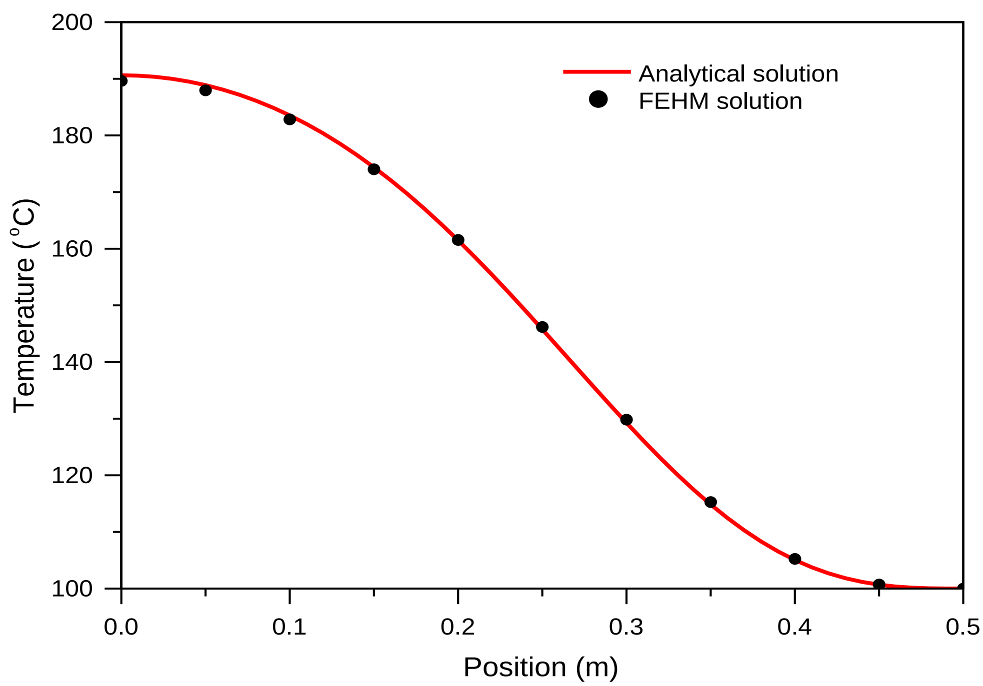

Figure 25. Comparison of FEHM and analytical solutions for 3-D heat conduction at time t = 2.16e4 seconds.

DRAFT 4/97

Table 44. Results of the test of 3-D heat conduction

V&V test	Maximum error	Maximum % error	RMS error
Temperature verus time at x = y = z = 0.0 m			
6-node triangular prisms	0.7855	0.5670	0.1164e-03
8-node quadrilateral polyhedrons	1.018	0.5273	0.6811e-04
4-node tetrahedral	1.245	0.6523	0.7690e-04
mixed elements	0.8470	0.4347	0.7936e-04
refined elements	1.267	0.6634	0.7874e-04
8-node quadrilateral polyhedrons with finite-volume option	1.018	0.5273	0.6811e-04
refined elements with finite-volume option	1.031	0.5341	0.6892e-04
Temperature versus position at t = 2.16e4 seconds			
6-node triangular prisms	0.7960	0.5284	0.1056e-02
8-node quadrilateral polyhedrons	0.9910	0.5199	0.1065e-02
4-node tetrahedral	1.243	0.6521	0.1158e-02
mixed elements	0.8210	0.4402	0.9981e-03
refined elements	1.265	0.6636	0.1124e-02
8-node quadrilateral polyhedrons with finite-volume option	0.9910	0.5199	0.1065e-02
refined elements with finite-volume option	1.005	0.5272	0.1076e-02